Investigations of Chemosynthetic Communities on the Lower Continental Slope of the Gulf of Mexico

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LONG-TERM GOALS

The long-term goals of this study are to add to the understanding of the oceanography and ecology of the deep-sea with emphasis on cold seep communities and hard bottom communities on the Gulf of Mexico (GoM) continental slope. Preliminary studies have shown that seep communities at the slope base are different from those on the upper slope, in much the same way that the normal background fauna differ. Compared to the upper-slope, there is limited understanding of seep and other hard bottom communities below 1,000 meters in the Gulf of Mexico. TDI-Brooks International's project team will meet MMS' information needs concerning the location and function of seep communities below 1,000 meters.

OBJECTIVES

The objectives of this study are:

- To characterize known, or newly discovered chemosynthetic communities at depths below 1,000 meters in the central and western Gulf of Mexico;
- To characterize all other hard bottom biological communities encountered regardless of association with active hydrocarbon seep activity or living chemosynthetic community species in the central and western Gulf of Mexico;
- To determine the comparative degree of sensitivity of anthropogenic impacts for the above through a variety of approaches such as rarity, unique taxonomy/biodiversity, or other environmental risk assessment methodologies. This objective includes understanding how these deep communities are similar or different from their shallower water counterparts;
- To further develop successful assessment methodologies for correlation of remote sensing information such as bathymetry, seabed acoustic reflectivity, sub-bottom structure, and other geophysical signatures obtained by non-visual techniques with the "potential" presence of non-soft bottom biological communities at depths below 1,000 meters. The target objective is to provide some level of predictive capability that can be used by MMS to avoid impacts to lower slope sensitive biological communities such as presented by Roberts (2001) for upper slope communities; and
- Assessing and explain diversity distribution and abundance of marine species at depths below 1,000 m in the central and western Gulf, as well as improve the understanding of the functional role of marine species in areas of active hydrocarbon seep activity or living chemosynthetic communities.

These objectives will be accomplished through a combination of both exploratory work and more focused studies including process-based work on known communities.

APPROACH AND WORK PLAN

In order to meet the objectives outlined above, the following scientific and technical plan is being implemented.

- Compile and analyze all of the appropriate available data to predict the location of significant chemoautotrophic or other hard-bottom communities at depths >1,000 m in the GoM. This effort resulted in the selection of 10 – 20 sites for visitation during the Reconnaissance Cruise. In addition to providing specific locations for most of the dives for the first submersible cruise, ground-truth data collected during the Reconnaissance Cruise allows evaluation of the predictive value of the various criteria used for site selection and provides data on the types of communities present at the sites. Multivariate analysis of these data (geophysical and geochemical predictors, and presence/absence of various community types) allows initial testing and refinement of the hypotheses relating to community occurrence, and further testing on the subsequent submersible/ROV cruises. These analyses will be further enriched when selected sites are more intensively imaged and sampled for macro and microbiology and chemistry. A third level of information comes from mapping community occurrence type and density onto the high resolution maps of surficial geology and seafloor topography made at of each of the three to four primary study sites. Our “sub-goal” here is to enrich the predictive value of these high-resolution data sets to include the occurrence of different types of communities/ habitats on a spatial scale of meters.

- Characterize types of significant hard bottom communities we encounter. First order community characterization will be identification of component taxa and descriptions of communities present at different sites. Second order characterizations will include distributions and abundances of taxa with respect to chemistry and surficial geology and measures of community structure and function. Third order characterizations/analyses will include interactions with background fauna, taxonomic relations of species from key taxa to related species at other depths and in other areas, and community-level comparisons among sites and related communities at other depths and areas. All sites visited by submersible or ROV (including 6-7 in the first year) are at least preliminarily characterized with respect to surficial geology, geochemistry of sediments and epibenthic bottom water, types of communities present, microbial activities, and mega- and macrofaunal species present. At four sites we conduct more extensive survey and experimentation to better characterize and understand the communities, and test hypotheses relating to community composition, tubeworms, trophic interactions, and microbiology. During the submersible and ROV cruises we collect imagery that provides data on endemic species occurrence, distribution and densities, and visitation by vagrant mobile megafauna. We make quantitative collections of communities that provide the material needed for taxonomic, biogeographic, and trophic studies, and analyze the collections in ways that provide a variety of data on community structure and function as well as composition. We make *in situ* chemical measurements to describe the microhabitat chemistry of the major community types. We map the faunal distributions with respect to surficial geology and chemistry. We characterize the microbial communities in the sediments, and initiate temporal studies of the communities (with time lapse camera, base line imaging, and growth).
- Descriptions of the communities encountered and analyses of background fauna trapped, trawled and imaged over the course of the study will contribute to the assessment of diversity, distributions, and abundance of marine species below 1,000 m in the GoM. Correlation analyses of faunal occurrence with geologic features and seep chemistry will further contribute to the explanation of these patterns. Trophic analyses, time-lapse camera data, community analyses, and growth studies greatly improve our understanding of the functional role of many of the marine species encountered. By working under the auspices of the Census of Marine Life ChEss program and providing all data collected to their database, we assure widespread international access to all biodiversity and biogeography data collected.
- Direct determination of sensitivity of individual species to particular potential anthropogenic impacts is addressed through assessment of rarity and unique taxonomy/biogeography of key species and communities, biodiversity of communities, and by interpretation made in the context of the degree of similarity to related communities on the upper Louisiana slope and what is known about those communities. The comparisons of community-level associations to similar communities elsewhere, and the proposed vestimentiferan growth studies will strengthen the power of these analyses. Existing collaborations with molecular and classical taxonomic experts will facilitate the identification of unknown species. The molecular analyses of foundation and other

key species provide information necessary to detect significant levels of genetic isolation at any site, analyze relations to taxa at other sites, and determine bathymetric ranges of the meta-populations.

Key individuals participating in this work and their roles are: Dr. James Brooks (TDI-BI) is the project director and will take the lead in administration of this project and assist in the geochemical studies. Dr. Charles Fisher (PSU) coordinates the biological studies, Dr. Harry Roberts (LSU) coordinates the geological/geophysical studies, and Ms. Liz Goehring (PSU) coordinates the education and outreach activities. Dr. Erik Cordes will work with Fisher's team on studies of seep communities and take a leadership role on synthesis and publication of results for other hard bottom communities discovered. Dr. Stephane Schaeffer oversees molecular phylogenetic screening of foundation species and their symbionts (tubeworms, mussels and clams) and other potential new species (and symbioses), as needed. Dr. Robert Carney leads the studies of interactions with background fauna and trophic exchange between seep/hard bottom communities and larger mobile fauna. Drs. Fisher, Carney, and Cordes share responsibility for coordination with taxonomists and molecular phylogenists and proper curation of samples. Dr. Ian MacDonald directs the use of digital imagery in all phases of the study, from the initial site survey and selection process to site descriptions and contributions to faunal inventory. Dr. Samantha Joye is responsible for the microbial ecology and sulfide geochemistry studies. Dr. Tim Shank (WHOI) will phylogentically characterize new species of megafaunal crustaceans and include at least the shrimp in his ongoing biogeographic analyses. Dr. Bob Vreijenhoek (MBARI) will do the same with clams and their symbionts and other gastropods as needed. Limpets and snails will be sent to Anders Waren (Swedish Museum of Natural History) and chitons to Julia Sigwart (University College Dublin) for morphological characterization. Dr. Stéphane Hourdez (Stacione Biologique de Roscoff, France) leads the polychaete phylogenetic characterizations and descriptions of new species of polynoids and siboglinids (using both molecular and classical approaches). He also assists with molecular characterization of foundation species. Dr. Stephane Cairns (Smithsonian) oversees curation and identification of cnidarians, with assistance of Daphne Fautine (University of Kansas) and Dennis Opreska (Oak Ridge). Dr. Cheryl Morrison (USGS Leetown Science Center) will include any samples of *Lophelia pertusa* collected in her ongoing studies of the phylogeography and population genetics of this foundation coral species and also collaborate with Dr. Cairns by contributing to the molecular systematics of other hard corals, as needed. Dr. Sabine Stohr (Swedish Museum of Natural History) has agreed to examine all ophuiroids collected. Dr. Monika Bright and her research team (Univ. Vienna) will sort and identify meiofauna collected with mussel and tubeworm communities and in sediment cores. Other faunal groups will be sent to appropriate experts as needed. Additionally, two internationally recognized research groups from the Max Planck Institute of Marine Microbiology in Bremen will bring unique expertise and equipment to bear on the study. Dr. Nicole Dublier's group will use quantitative mRNA analyses to determine the relative activities of chemoautotrophic and methanotrophic symbiont populations in the dual symbiont-containing mussels. Dr. Antje Botieus' group will bring their *in-situ* seep-chemistry analysis system and expertise on the ALVIN and ROV cruises. Dr. Bernie Bernard coordinates the isotope, hydrocarbon and ancillary measurements. Dr. Thomas McDonald is the principal hydrocarbon chemist for the project. Dr. Gary Wolff is the project data manager, as he has been for many previous large, multi-disciplinary MMS projects. Ms. Susan Wolff is the project's technical editor. Ms. Suzanne Cardwell provides financial and project administrative support.

The work plan for the upcoming year includes the 2007 ROV Cruise**.** Details of the system and number of operation days available for this project in FY-2007 are being finalized. The PIs will submit proposals to both NOAA's Undersea Research Program (NURP) and NOAA's Office of Ocean

Exploration (OE) with the primary intent of increasing the number of operation days available for this project, and if possible to secure the ROV JASON-2 for the project. Considering this uncertainty, a very general plan based on priorities is:

- Comple the studies begun in 2006.
- Collect the time-lapse cameras and the contained data from each of the intensive study sites.
- Collect the stained tubeworm bushes from each of the most intensive study sites. By collecting intact aggregations whenever possible (using a bushmaster), we will replicate our community collections and significantly increase our descriptive and comparative power for the community analyses.
- Re-mosaic each of the communities surveyed in 2006, and re-survey chemical conditions within these aggregations. The amount of time spent on this task will depend in part on any changes apparent in the communities.
- Targeted collection of species that show a high likelihood of providing special ecological insight based on 2006 collections, or were missed in 2006. These animals may include species of particular interest for trophic studies, species with specific associations to particular features or other species, and mobile species that were abundant in photographs but not in the quantitative collections.
- Collect any additional data necessary to complete the GIS database for these sites.

Our focus in 2007 will change to a combination of re-visitation of the other sites visited in 2006 and preliminary survey of any new sites discovered in the interim or not visited in 2006 because of time constraints. This decision will be based on evaluation of data collected up until this point in the program and made in consultation with MMS.

WORK COMPLETED

The historical data review was completed during the first few months of 2006. The Reconnaissance Cruise was conducted on the TDI-Brooks research vessel R/V GYRE from 11 to 25 March 2006, using over-the-side imaging equipment and shipboard acoustic methods and was the initial cruise conducted for this contract. The cruise was completed in two week-long legs with an interim port call in Venice, LA. Leg I (11-18 March) was dedicated to drift camera work to survey the seabed at selected sites. Leg II (19-25 March) involved both drift camera and trawling/box core work efforts for isotopic characterization of the seep-background interactions near seep sites in the deep GoM. Twenty-four sites were studied. The cruise mobilized and embarked from Freeport, Texas. The objective was to provide timely input for the site selection process for the subsequent ALVIN expedition (May 2006).

The Deep Chemosynthetic Community Characterization Cruise (DCCC) was conducted on the Wood's Hole Oceanographic Institute (WHOI) research vessel R/V ATLANTIS and the ALVIN Deep Submergence Vehicle (DSV) from 7 May – 2 June 2006, and was the second cruise conducted for this contract. The cruise mobilized and embarked from Key West, Florida, and de-mobilized at Galveston, Texas. Twenty-four dives were completed on ALVIN. At some sites, multiple dives were made while at other sites only a single dive was completed.

Post-cruise reports were completed for both of these cruises and were submitted to MMS. The data from these two cruises was up-loaded to a site located on the TDI-Brooks International Website. All program researchers have password-protected access to these data.

RESULTS

Reconnaissance Cruise –

- Trawls were completed at three sites, MC685, MC548 and AT209. Two box cores were collected at site WR265.
- The number of survey photos captured with the bottom in view (BIV) was 10,922.
- Site characterization and evaluation was completed on 24 sites.
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DCCC Cruise –

- Multiple dives were made at four sites and the geology, geochemistry, microbiology and biology of the sites thoroughly characterized.
- Longer-term studies were established at these sites to determine growth rates of some of the animals, monitor for visitation by mobile deep-sea fauna such as larger fishes and crabs, and follow the fine scale changes in seepage patterns and community composition (Figure 1).
- A camera dedicated to taking down-looking pictures was used to construct mosaics of any new animal communities discovered.
- Push cores were collected for geological, geochemical, and microbial analyses and for the study of some of the tiny animals that may live between the sand grains at the deep seep sites.
- A chemical analyzer was used to characterize new habitats.
- Collections for study of the larger animals that live at the sites was begun.
- Communities with full mosaics were revisited and chemical analyzers used to characterize the chemistry in and around individual animals identified in the images.
- Quantitative collections of other tubeworm communities, mussel beds, and clam beds were made using specialized collection tools built specifically for this task.
- Ten nighttime trawls were completed.
- Traps and cameras were used to capture and identify the visitors to the seep and coral communities being studied to aid in characterizing the more mobile fauna around the sites.
- A rotary camera, left on the bottom for up to a year, is housed in a special glass tube and periodically “wakes up” to take 12 consecutive pictures as it rotates on a turntable.
- More than 14,000 down-camera and 400 macro images were recorded.
- Acoustic Doppler Current Profilers (ADCP) were operated on station and with the ship underway to obtain an integrated picture of current direction and velocity in the upper 1,000 m of the water column.

IMPACT AND APPLICATIONS

National Security

This program will provide critical information on the location and function of seep communities to MMS. As manager of the nation’s seafloor mineral resources, MMS will use this information to aid in the development of critical energy resources, which may affect domestic energy production.

Economic Development

Increased energy and mineral production will have a positive economic impact at numerous levels in industry.

Figure 1. Tubeworms at the AC818 site were stained to study their growth rate. This aggregation will be collected in 2007 to determine growth over the coming year.

Quality of Life

Information on the location and functioning of seep communities gathered by this program will have a positive impact on other ocean users, the natural environment, and the human environment. It will aid in minimizing the environmental impact on sensitive habitat and mitigate any potential damage to these communities.

Science Education and Communication

The development of educational outreach material for this program will have two phases. Phase I will involve developing new “Classroom to Sea” Gulf of Mexico labs to help students understand the remote environment of the deep sea by making direct comparisons with their own environment. Phase II will involve disseminating the labs with teacher training workshops. The three-day teacher course will provide teachers with information about cutting-edge research, relevant OE lessons, inquiry skills related to the specific labs and the data analysis required. The short course will coincide with the 2007 cruise so that teachers can access the cruise Website, observe the at-sea lab, and download the data.

TRANSITIONS

Data collected during this study will be provided to the ChEss database which is a component of the Census of Marine Life (CoML) Ocean Biogeographic Information System (OBIS) data base. All gene sequences will be submitted to the international genetic data base, GenBank. The work proposed here will contribute significantly to the goals of the Atlantic Equatorial Belt studies of the ChEss program, particularly the components that will allow interpretation of our findings in the context of seeps around the world. The second component of the CoML program relevant to this project is the CoMargE component. Dr. Carney, co-director of CoMargE and supported by the MMS Coastal Marine Program, will transfer past MMS survey data into the CoML OBIS database system. Therefore, procedures and software are already in place to carry out data transfer to this International Marine Life database.

RELATED PROJECTS

Studies closely related to this effort include other chemosynthetic and deep water ecosystem studies funded by MMS.

1) Chemosynthetic Ecosystems Study (MMS Report 95-0021). http://www.gomr.mms.gov/homepg/regulate/environ/studies/1995/95-0021%20Vol%20I.pdf.
2) Stability and Change in Gulf of Mexico Chemosynthetic Communities (MMS Report 2002-036). http://www.gomr.mms.gov/homepg/regulate/environ/studies/2002-036.pdf.
3) The Deepwater Program: Northern Gulf of Mexico Continental Slope Habitat and Benthic Ecology (MMS contract 1435-01-99-CT-30991).

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